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Abstract

A polarized proton beam extracted from SATURNE II was scattered on an unpolarized CH_2 target. The angular distribution of the beam analyzing power A_{oono} was measured at large angles from 1.98 to 2.8 GeV and at 0.80 GeV nominal beam kinetic energy. The same observable was determined at the fixed mean laboratory angle of 13.9° in the same energy range. Both measurements are by-products of an experiment measuring the spin correlation parameter A_{oonn}.
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1. Introduction

This experiment is a part of the nucleon-nucleon (NN) program at SATURNE II devoted to a study of the energy and angular dependence of scattering amplitudes. We present results from single scattering of the polarized proton beam by protons in a small CH_2 target. The data were obtained as a by-product of an experiment measuring the spin correlation parameter A_{oonn} and the rescattering observables D_{onon} and K_{onno}, using the same beam and the same apparatus, with a polarized proton target (PPT). The preliminary results of this experiment are listed in Ref. [1]. Data were recorded at 18 beam energies from 1.98 to 2.80 GeV at angles around 90° CM. Meaurements were also carried out at 0.80 GeV at smaller angles.

Another part of the data was provided by the beam-line polarimeter. The polarimeter arms for scattered protons were positioned at the fixed forward laboratory angle of 13.9°. Asymmetries of $p-CH_2$ scattering were measured at 20 energies in the same energy range. From these data the pp elastic scattering asymmetries were calculated using the accurately determined ratio of pp and $p-CH_2$ asymmetries [2]. This ratio depends on the given polarimeter.

The beam polarization at each energy was determined independently of the present measurements and was used to calculate the beam analyzing power A_{oono} for both measurements.

The formalism for this experiment is given in Section 2. Existing pp analyzing power data are discussed in Section 3. The beam and the polarimeter are described in Section 4, and the NN experimental setup is discussed in Section 5. The results are presented in Section 6. They are compared with predictions of two phase shift analyses (PSA) [3,4].

2. Determination of the analyzing power

Throughout the paper we use the NN formalism and the four-index notation of observables given in Ref. [5]. The subscripts of any observable X_{pqij} refer to the polarization states of the scattered, recoil, beam, and target particles, respectively.

For so-called "pure experiments" the polarizations of the incident beam and target particles in the laboratory system are oriented along the basic unit vectors

$$\boldsymbol{k}, \qquad \boldsymbol{n} = [\boldsymbol{k} \times \boldsymbol{k}'], \qquad \boldsymbol{s} = [\boldsymbol{n} \times \boldsymbol{k}]. \tag{2.1}$$

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where $\boldsymbol{k}$ and $\boldsymbol{k}'$ are the beam and scattered particle directions, respectively, and $\boldsymbol{n}$ is the normal to the scattering plane.

The more general case of the present experiment is a single scattering of a polarized proton beam on a polarized proton target (PPT), where observables with indices p and q are absent.

The unit vectors (2.1) and beam or target polarization vectors $\boldsymbol{P_B}$ and $\boldsymbol{P_T}$ in the scattering frame may be expressed by azimuthal angle ϕ-functions. The vectors (2.1) in the reference frame $(\boldsymbol{h}, \boldsymbol{v}, \boldsymbol{k})$ (horizontal perpendicularly to the beam, vertical and beam direction) are:

$$\boldsymbol{s} = (\cos\phi, \sin\phi, 0), \qquad \boldsymbol{n} = (-\sin\phi, \cos\phi, 0), \qquad \boldsymbol{k} = (0, 0, 1). \tag{2.2}$$

The beam and target polarization vectors, arbitrarily oriented, are expressed by components in the reference frame:

$$\boldsymbol{P_B} = (P_{Bh}, P_{Bv}, P_{Bk}), \qquad \boldsymbol{P_T} = (P_{Th}, P_{Tv}, P_{Tk}). \tag{2.3}$$

If $\boldsymbol{P_B}$ and $\boldsymbol{P_T}$ are oriented along the vertical direction ($P_{Bv} = \pm|\boldsymbol{P_B}|$, and ($P_{Tv} = \pm|\boldsymbol{P_T}|$, the general scattering formula in Ref. [5] reduces to:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \Big(1 + (A_{oono}P_B + A_{ooon}P_T)\cos\phi + A_{oonn}P_B P_T \cos^2\phi + A_{ooss}P_B P_T \sin^2\phi\Big), \tag{2.4}$$

where $(d\sigma/d\Omega)_o$ is the unpolarized differential cross section. The quantities $d\sigma/d\Omega$, $(d\sigma/d\Omega)_o$, A_{oono}, A_{ooon}, A_{oonn} and A_{ooss} are functions of scattering angle and energy. Other observables are equal to zero, due to fundamental laws and to conditions of experiment. The Pauli principle impose $A_{oono} = A_{ooon}$.

Background is due to inelastic pp contributions and to scattering of polarized protons on unpolarized target nuclei. The pp inelastic part is strongly reduced by the elastic event selection. The latter part is dominant and depends on the beam polarization. The background can be considered as a dilution d of the proton spin contribution to the differential cross section:

$$(1-d)\,[pp \to pp] + d\,[\text{background}]. \tag{2.5}$$

It has been determined either by measurements with an unpolarized hydrogenless target, or by a fit over wings of θ and ϕ distributions for each beam polarization direction. The background subtraction results in a multiplication of any pp observable in (2.4) by the factor $(1-d)$ and in an addition of the factor $dA(\text{back})$ to the corrected polarized beam analyzing power $(1-d)A_{oono}$. Here $A(\text{back})$ is the background analyzing power.

The mean ϕ-acceptance of our apparatus is ±8° around 0°. The observables for which

$$\cos\phi \sim \cos^2\phi \sim 1, \tag{2.6}$$

are predominant. The mean value of $\sin^2\phi$ is ~0.007.

On the other hand, a magnetic field close to the target may bend particles and disturb the ϕ-symmetry of the vertical apparatus acceptance. A term $\epsilon(\text{instr.})\sin\phi$, added in (2.4) checks this instrumental effect.

For a given energy, Eq. (2.4) provides four relations for the two opposite directions of P_B and P_T, respectively. These polarizations are common to all scattering angles.

The opposite proton beam polarizations at SATURNE II for the two ion source polarized states, were accurately measured in a dedicated experiment discussed in detail in Ref. [6]. It was found that $P_B = |P_B^+| = |P_B^-|$. Only these two states of the ion source with large polarizations were used. The two "unpolarized" ion source states are polarized to ±6%.

For the PPT $|P_T^+| \neq |P_T^-|$, but any P_T was measured by the same apparatus and a possible normalization error results in a common factor F, which multiply both P_T^+ and P_T^-.

If the absolute value of P_B or F is unknown, we can solve four relations (2.4) with different beam and target polarizations for three quantities: P_B (or F), $A_{oono} = A_{ooon}$, and A_{oonn} and relate P_B and F. For this purpose one imposes the statistical equality of $A_{oono}(av)$ and $A_{ooon}(av)$ values, averaged over the same angular range. Either P_B or F varies, whereas the other quantity is fixed, until the equality $A_{oono}(av) = A_{ooon}(av)$ is obtained. Since the errors of the two averaged observables are small with respect to the beam or target polarizations, the errors of P_B and FP_T will be of the same order. Comparison of the beam and target analyzing powers [7] was used to determine P_B at all high energies. Additionally a check of F was made at 0.80 GeV, where the pp analyzing power is well known.

3. Existing pp analyzing power data

Previously our collaboration obtained results at SATURNE II on $A_{oono} = A_{ooon}$ with the polarized beam and target. Those covered the angular region from 20° to 95°CM at 1.596, 1.796, 2.096, 2.396, and 2.696 GeV [8]. Close to these energies and angles A_{oono} was measured simultaneously with the polarized beam and with an unpolarized CH_2 target [8]. The A_{ooon} data [9] were measured at angles from 19° to 52°CM at 2.16, 2.18, 2.20, 2.22, 2.24, 2.26, and 2.28 GeV. They were obtained with an unpolarized beam and with a PPT in order to study the region close to the accelerator proton depolarizing resonance $\gamma G = 6$ at 2.202 GeV. A_{oono} data at very small angles were obtained between 0.94 and 2.44 GeV [10]. None of the previously mentioned results needs any corrections for the recently determined polarizations of the "unpolarized" ion source states [6].

At other accelerators, but within our energy range, there exist the SATURNE I results at 3 GeV of Ref. [11], the BNL results at 1.63 and 2.24 GeV [12], LBL data at 1.70, 2.85, and 3.50 GeV [13], and CERN data at 1.958 GeV [14]. All these data were measured with a proton beam with a relatively small uncertainty of the energy. Larger energy uncertainties exist for the ANL-ZGS data at 1.732, 1.967, 2.138, 2.444, 2.927, and 3.561 GeV from Ref. [15], at 1.967 GeV [16], at 2.205 and 3.170 GeV

from Ref. [17], and at 2.301 GeV from [18]. Quasielastic pp data were obtained with a deuterium target and the ANL-ZGS polarized proton beam at 2.205 [19,20] and at 3.170 GeV [19]. Finally, A_{oono} data below 2.0 GeV were measured at the fixed laboratory recoil angle of 68° with an internal target during polarized beam acceleration at KEK [21]. The beam polarization for the latter measurement was fairly small.

The data measured before 1983 were fitted and analyzed in Ref. [22]. In the energy region under discussion, the authors observed a considerable difference in the absolute polarization values between the different data sets. Common fits averaging these sets suggested to normalize the data in Refs. [13,16,18] downward by 10%, 8%, and 8%, respectively. The data in Refs. [15,19] needed to be normalized upwards by 15% and 12%. The conclusions based on fits including the SATURNE II data are similar to those in Ref. [22].

4. Beam polarimeter

The vertical polarization of the extracted proton beam at SATURNE II was flipped at each accelerator spill. The extracted beam polarization was monitored by the beam line polarimeter [23], which has two pairs of kinematically conjugate arms in the horizontal plane and beam intensity monitors in the vertical plane. It measured the left-right (L-R) scattering asymmetry $\epsilon = P_B A$, where A is the analyzing power. In the present experiment the p−CH2 asymmetry was measured at $\theta_1 = 13.9°$ in the laboratory frame and the pp elastic scattering asymmetry was deduced using the known ratio of the CH_2 and the pp asymmetries for this polarimeter [2]. The polarimeter target was a rectangle 5 mm thick, 2 mm wide, and 15 mm high. Incident protons have a nominal kinetic energy from the accelerator. The full scattering angle interval $\Delta\theta_1$, accepted by the polarimeter definition counters, was ±1.9° in the laboratory frame. This provided $\Delta\theta_1 = \pm 1°$ of the half width at the half maximum for the polarimeter conjugate angle distribution. The $\cos\phi$-dependence is averaged over the polarimeter counter acceptance. The beam intensity of 2×10^8 protons/spill allowed the use of this polarimeter simultaneously with the data taking by the following experimental equipment.

5. NN experimental setup

The beam passed through three thin windows, through the target of the second beam polarimeter, and entered the Saclay frozen spin PPT, 35 mm thick, 40 mm wide, and 49 mm high, containing pentanol [24]. The target worked in the frozen spin mode at a small magnetic holding field of 0.33 Tesla.

The proton beam outgoing from the PPT loses about 8 MeV with respect to the nominal accelerator energy. A CH_2 target, 10 mm thick and 15 mm in diameter, was placed 16 cm downstream from the PPT.

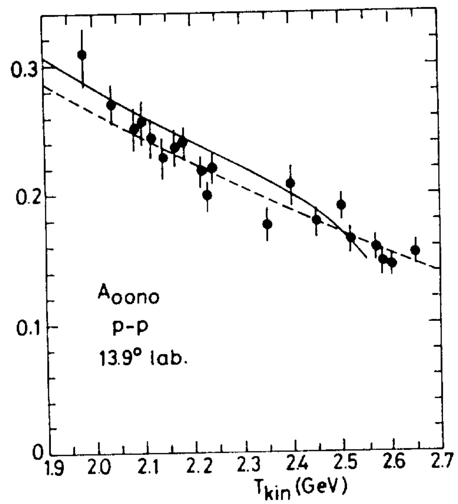

Fig. 1. Results of the A_{oono} measurement at a fixed laboratory angle of 13.9°. The dashed line represents the quadratic fit to all existing data (Eq. (6.2)) [33]. The predictions of the energy dependent PSA [3] are given by the solid line. The present data were not introduced in the latter.

The measurements of pp scattering from the PPT as well as from the additional CH_2 target were carried out using the NN experimental setup. This apparatus and the subsequent analysis of the data were described in detail in Ref. [7]. The setup consisted of a two-arm spectrometer with an analyzing magnet in the forward arm. Each arm was equipped with single scintillation counters and counter hodoscopes selecting events with pairs of charged particles. The triggers for events scattering off the PPT and the CH_2 target were different. Either one of the triggers gated the eight multi-wire proportional chambers (MWPC's) with three wire planes each. The acceptance of each arm in the laboratory frame was $\sim \pm 4.5°$ vertically and 23° horizontally. The mean ϕ acceptance of both arms was limited to $\pm 8°$. The pp-elastic events from both targets were selected in the off-line analysis by kinematic conditions, bending of scattered protons in the analyzing magnet, and by time of flight information. The ϕ-dependence of events was taken into account as described by Eq. (2.4).

The aim of the measurements using simultaneously the PPT and an unpolarized target is a check of the normalization of events recorded with two opposite PPT polarizations. This is due to the fact that the P_T was usually reversed after several hours of data taking, whereas P_B was flipped every spill.

Accurate measurements at 0.80 GeV were undertaken in order to check the PPT polarization. This is an energy where the pp analyzing power is well known, having been measured, for example, at SATURNE II, SATURNE I, LAMPF, CERN, Gatchina, the BNL Cosmotron, and the ANL-ZGS. The majority of these data are listed in compilations [25–27] and are referenced in Refs. [8,28]. Moreover, the beam polarization around 0.8 GeV was checked by the deceleration method [29] at SATURNE II. At

Table 1
The analyzing power A_{oono} at $\theta_1 = 13.9°$ in the pp elastic scattering of polarized protons on the unpolarized CH_2 target. The beam-line polarimeter was used and results at the same energy were averaged over different running periods. Errors of experimental values contain statistical uncertainties, random-like errors from individual result dispersions and normalization errors in the determination of the beam polarizations. Total errors contain systematic errors due to the angular bin width estimated to be ±5% of the pp analyzing power. The errors were added in quadrature

T_{kin} (GeV)	θ_{CM} (deg)	Exp. value	Total error ±
1.980	39.1 ± 2.7	0.310 ± 0.011	0.019
2.040	39.4 ± 2.7	0.272 ± 0.008	0.016
2.080	39.5 ± 2.7	0.251 ± 0.011	0.017
2.100	39.6 ± 2.7	0.258 ± 0.011	0.017
2.120	39.7 ± 2.7	0.244 ± 0.008	0.016
2.140	39.8 ± 2.7	0.228 ± 0.013	0.016
2.160	39.9 ± 2.7	0.237 ± 0.007	0.014
2.180	40.0 ± 2.7	0.242 ± 0.006	0.014
2.220	40.2 ± 2.8	0.218 ± 0.005	0.012
2.230	40.2 ± 2.8	0.199 ± 0.006	0.012
2.240	40.3 ± 2.8	0.221 ± 0.006	0.013
2.350	40.8 ± 2.8	0.176 ± 0.009	0.012
2.400	41.0 ± 2.8	0.208 ± 0.011	0.015
2.450	41.2 ± 2.8	0.179 ± 0.007	0.011
2.500	41.4 ± 2.8	0.192 ± 0.007	0.012
2.520	41.5 ± 2.8	0.165 ± 0.006	0.011
2.570	41.7 ± 2.8	0.160 ± 0.005	0.010
2.580	41.8 ± 2.8	0.149 ± 0.006	0.010
2.600	41.8 ± 2.8	0.146 ± 0.005	0.010
2.650	42.1 ± 2.8	0.155 ± 0.007	0.010

energies above 1.9 GeV the P_T was fixed at the value measured by the polarized target NMR probe. The P_B value was then determined using Eq. (2.4). The by-products of these measurements, using the scattering of polarized protons in the unpolarized target ($P_T = 0$) are listed below.

6. Results and discussion

The results obtained from the polarimeter are the asymmetries $\epsilon(p{-}CH_2)$. In order to obtain the pp elastic scattering asymmetry $\epsilon(pp)$, measurements with a carbon target are needed as well. On the other hand the ratio:

$$R(T_{kin},\theta_1) = \epsilon(pp)/\epsilon(p{-}CH_2), \tag{6.1}$$

is independent of the beam polarization P_B. Previously these ratios were accurately determined at different scattering angles and energies [2,30–32]. More recent data confirm the energy dependence of R values, listed in Ref. [2] and based on about 200 measurements with the same polarimeter. These R values were used to deduce the $\epsilon(pp)$ values at 13.9°lab at all energies. The P_B values [1], independently determined (Section 2),

Table 2
The analyzing power A_{oono} in the pp elastic scattering of polarized protons on the unpolarized CH_2 target. The beam polarization was oriented in the vertical direction. The beam kinetic energy and the CM angles in degrees for the target center are listed. The quoted errors include statistical uncertainties and random-like errors in the determination of the absolute P_B value. The systematic normalization error in the beam polarization was ±(3 to 5)% (relative)

θ_{CM}	Exp. value	θ_{CM}	Exp. value	θ_{CM}	Exp. value
T_{kin} = 0.792 GeV		T_{kin} = 1.972 GeV		T_{kin} = 2.032 GeV	
54.1	+0.505 ± 0.053	73.4	+0.124 ± 0.018	73.6	+0.135 ± 0.014
59.0	+0.455 ± 0.010	77.0	+0.137 ± 0.016	77.0	+0.110 ± 0.010
62.1	+0.442 ± 0.005	80.9	+0.072 ± 0.016	80.9	+0.085 ± 0.010
66.0	+0.394 ± 0.005	85.0	+0.034 ± 0.017	85.1	+0.039 ± 0.012
69.9	+0.365 ± 0.005	89.0	+0.001 ± 0.020	89.0	+0.006 ± 0.011
74.0	+0.313 ± 0.006	92.9	−0.005 ± 0.017	93.0	−0.025 ± 0.011
77.9	+0.260 ± 0.006	97.0	−0.062 ± 0.018	97.0	−0.071 ± 0.012
82.0	+0.174 ± 0.007	100.5	−0.065 ± 0.020	100.6	−0.126 ± 0.012
85.9	+0.097 ± 0.007			103.9	−0.148 ± 0.026
88.5	+0.001 ± 0.028				
T_{kin} = 2.112 GeV		T_{kin} = 2.152 GeV		T_{kin} = 2.172 GeV	
73.6	+0.146 ± 0.020	74.0	+0.155 ± 0.020	74.0	+0.170 ± 0.023
77.0	+0.125 ± 0.016	77.0	+0.138 ± 0.012	77.0	+0.127 ± 0.014
81.0	+0.088 ± 0.016	81.0	+0.087 ± 0.012	81.0	+0.122 ± 0.014
85.0	+0.049 ± 0.017	85.1	+0.061 ± 0.014	85.0	+0.066 ± 0.016
88.9	+0.004 ± 0.019	88.8	+0.020 ± 0.015	88.8	+0.033 ± 0.017
93.0	−0.016 ± 0.020	93.1	−0.020 ± 0.015	93.1	−0.015 ± 0.017
96.9	−0.068 ± 0.021	96.9	−0.090 ± 0.015	96.9	−0.088 ± 0.018
100.6	−0.109 ± 0.024	100.6	−0.136 ± 0.015	100.4	−0.111 ± 0.031
T_{kin} = 2.212 GeV		T_{kin} = 2.222 GeV		T_{kin} = 2.232 GeV	
74.1	+0.160 ± 0.020	72.3	+0.166 ± 0.049	74.1	+0.137 ± 0.030
77.0	+0.126 ± 0.011	75.1	+0.153 ± 0.017	77.1	+0.190 ± 0.015
81.0	+0.094 ± 0.011	79.0	+0.127 ± 0.016	81.0	+0.124 ± 0.014
85.0	+0.048 ± 0.012	82.9	+0.101 ± 0.017	85.0	+0.073 ± 0.016
89.0	+0.001 ± 0.012	87.0	+0.041 ± 0.018	89.0	+0.025 ± 0.016
93.0	−0.052 ± 0.012	91.0	−0.011 ± 0.018	93.0	−0.071 ± 0.017
97.0	−0.096 ± 0.012	95.0	−0.071 ± 0.019	97.0	−0.076 ± 0.017
100.6	−0.113 ± 0.013	99.0	−0.055 ± 0.020	100.6	−0.166 ± 0.017
		102.2	−0.065 ± 0.030		
T_{kin} = 2.342 GeV		T_{kin} = 2.442 GeV		T_{kin}=2.492 GeV	
77.2	+0.164 ± 0.020	77.3	+0.159 ± 0.019	77.2	+0.142 ± 0.027
81.0	+0.121 ± 0.019	80.9	+0.163 ± 0.018	80.9	+0.177 ± 0.025
85.0	+0.098 ± 0.021	84.9	+0.051 ± 0.019	84.8	+0.087 ± 0.028
89.0	+0.002 ± 0.021	89.0	+0.054 ± 0.019	89.2	+0.034 ± 0.032
93.0	−0.024 ± 0.022	93.0	−0.055 ± 0.021	93.0	−0.061 ± 0.032
97.0	−0.089 ± 0.022	97.0	−0.090 ± 0.020	97.0	−0.112 ± 0.033
100.8	−0.134 ± 0.023	100.5	−0.172 ± 0.024	100.4	−0.149 ± 0.046

Table 2 — continued

θ_{CM}	Exp. value	θ_{CM}	Exp. value	θ_{CM}	Exp. value
T_{kin} = 2.512 GeV		T_{kin} = 2.562 GeV		T_{kin}=2.572 GeV	
77.3	+0.157 ± 0.018	77.5	+0.168 ± 0.029	77.2	+0.167 ± 0.019
80.9	+0.128 ± 0.016	81.0	+0.136 ± 0.025	81.0	+0.151 ± 0.018
84.9	+0.075 ± 0.017	84.9	+0.092 ± 0.026	84.9	+0.079 ± 0.019
89.1	+0.042 ± 0.018	89.0	−0.016 ± 0.028	89.0	+0.010 ± 0.020
93.0	−0.028 ± 0.020	93.0	−0.063 ± 0.028	93.0	−0.055 ± 0.022
97.0	−0.118 ± 0.019	96.9	−0.118 ± 0.028	97.0	−0.093 ± 0.023
100.3	−0.147 ± 0.024			100.1	−0.083 ± 0.034
T_{kin} = 2.592 GeV		T_{kin} = 2.642 GeV		T_{kin}=2.792 GeV	
77.7	+0.175 ± 0.024	77.3	+0.187 ± 0.031		
80.9	+0.137 ± 0.019	81.0	+0.166 ± 0.029	80.1	+0.141 ± 0.049
84.9	+0.091 ± 0.021	84.9	+0.094 ± 0.032	83.9	+0.118 ± 0.049
89.1	+0.036 ± 0.025	88.9	+0.112 ± 0.043	87.9	+0.090 ± 0.055
93.0	−0.007 ± 0.024	92.8	+0.003 ± 0.043	92.0	+0.014 ± 0.053
97.1	−0.148 ± 0.025	97.0	−0.143 ± 0.051	96.0	−0.093 ± 0.055
100.3	−0.122 ± 0.035				

and $\epsilon(pp)$ results from the polarimeter measurements, provided the analyzing power results at $\theta_1 = 13.9°$, listed in Table 1.

The quadratic fit to the present and previously existing A_{oono} data at $\theta_1 = 13.9°$, as a function of the beam kinetic energy $T_{kin} = T$ gives:

$$A_{oono}(13.9° \text{ lab}) = 0.79849 - 0.33118T + 0.032327T^2, \tag{6.2}$$

where $T = T_{kin}$ is in GeV. The fit described 75 contributing points in the energy range from 1.6 to 3.5 GeV with $\chi^2 = 87.39$ [33].

The present results and the fit of Eq. (6.2) are plotted in Fig. 1 as a function of the beam kinetic energy. In addition, the predictions are shown of the energy dependent PSA [3], carried out below 2.55 GeV, which do not include the present data.

The data measured with the additional CH_2 target downstream from the PPT were analyzed by the standard off-line procedure described in Ref. [7]. The observables were extracted by the method described in Ref. [34]. Using again the independently determined P_B values, the results of $A_{oono}(pp)$ are listed in Table 2. As an example, the results at 2.032 and at 2.112 GeV are plotted in Fig. 2a, and the results at 2.342 and at 2.442 GeV are shown in Fig. 2b. The polarimeter results at 2.10 and 2.40 GeV are added. One observes that the slope of the angular dependence in the vicinity of 90° change considerably with energy. The present data are compared with existing results at 2.096 and 2.396 GeV from Ref. [8] and with predictions of the Saclay-Geneva PSA [4] and the PSA of Ref. [3] at 2.10 GeV and at 2.40 GeV, respectively. The present results were introduced in Ref. [4], but were not included yet in Ref. [3].

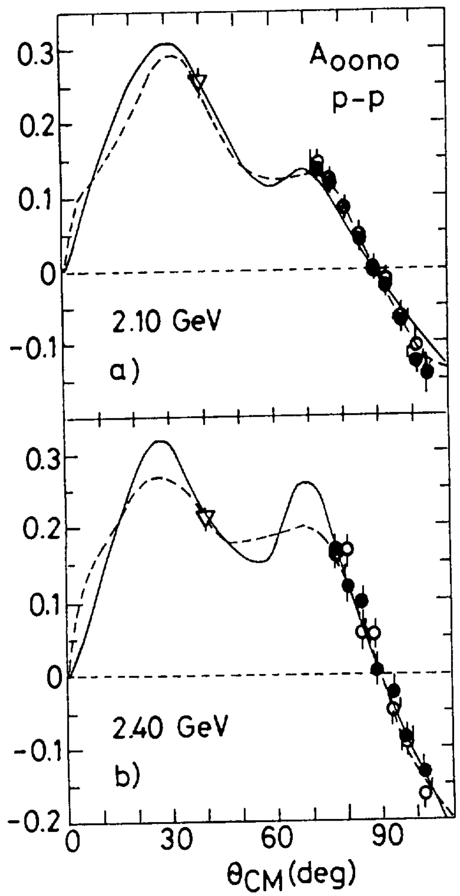

Fig. 2. Results at 2.032 GeV (black dots), at 2.100 GeV (triangle), and at 2.112 GeV (open circles) are plotted in (a). The results at 2.342 GeV (black dots), at 2.400 GeV (triangle), and at 2.442 GeV (open circles) are shown in (b). The present data are compared with the previous measurements at 2.096 and 2.396 GeV from Ref. [8] (crosses), with the predictions of the Saclay–Geneva PSA [4] (dashed curve) and PSA of Ref. [3] (solid curve) at 2.10 and 2.40 GeV, respectively. The present results were not included in the PSA [3]. They were introduced in the PSA of Ref. [4] together with the preliminary data of Ref. [1].

7. Conclusions

The present results improve the existing database for *pp* elastic scattering. The results were obtained in small energy steps and are important for the angular dependence of this observable at large CM angles. The additional data taken with the polarimeter will help to establish the accurate energy dependence of A_{oono} at small angles needed for the proton beam polarization measurements.

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